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| B | 302 | LUXEMBURG | 930 |
| AZ | 419 | TURIN | 935 |
| LH | 1122 | NEAPEL | 935 |
| LH | 1906 | MADRID | 935 |
| LH | 1022 | STUTTGART HBF | 935 |
| AF | 1701 | LYON | 940 |
| AY | 822 | HELSINKI | 940 |
| UA | 071 | ST FRANCISCO-DALLAS | 940 |
| AF | 743 | PARIS | 940 |
| LH | 1118 | VENEZIA | 940 |
| DL | 023 | DALLAS | 950 |
| KLM | 892 | AMSTERDAM | 950 |

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Edinburgh Airport radar track analysis

Findings report

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Report

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1 Introduction

To70 analysed historical radar data of Edinburgh Airport at the request of the EANAB Aviation Consultancy Sub-Group (Sub-Group). This findings report brings together the different analyses and elaborates on the applied methods and the conclusions which can be drawn from the conducted analyses.

1.1 The research

To70 has conducted the analysis of historical flight and radar data of Edinburgh Airport in three work packages (WPs). These analyses focused on:

- WP1 (May-July 2018)
 - Statistics on number of aircraft, runway/route usage, aircraft-types and flight-times;
 - Flight-patterns of consecutive years and comparison between these flight-patterns.
- WP2 (Nov-Dec 2018)
 - Comparison of flight patterns with schematic representation of the SID procedure
 - Analysis of measured vertical profiles. This resulted in altitude/distance and speed/distance plots of aircraft types Airbus A319 and Boeing 737 in consecutive years.
- WP3 (Feb 2019)
 - Comparison of the two measured vertical profiles of altitude and speed to the ANCON profiles, which are used as input to the ANCON model to produce the SEL.

1.2 Reading guide

The analysis described above produced a high volume of graphs and other figures, which were delivered to the Sub-Group. For the purpose of readability, these graphs and other figures are provided in separate appendices and are not included in this findings report. This report will first go into more detail on how the research was conducted in Chapter 2. After that, Chapter 3 presents the conclusions of the conducted research.

2 Research

2.1 Methods and sources

All the analysis conducted by To70 used flight radar data, provided by Casper Flight Tracking¹. The flight radar data shows the track flown by an aircraft and its speed and altitude. The data also provides a wide range of additional information on a flight, including its callsign, aircraft type, departure runway and name of the SID (Standard Instrument Departure) procedure (“the departure route”).

Other sources used for the analysis are:

- Schematic representation of the SID procedure. These are not strict lines, but a reference line of the SID procedure. The reference lines were provided to To70 by the Sub-Group, who got them from the Environmental Research and Consultancy Department (ERCD) of the UK Civil Aviation Authority (CAA).
- SEL Contours which graphically represent equal levels of noise exposure around the airport. The noise exposure is expressed in the Single Event Level (SEL) noise metric. A SEL contour shows the geographical area in which a SEL value is reached from a single noise activity (such as a plane taking off). The SEL contours were provided to To70 by the Sub-Group, who got them from the Environmental Research and Consultancy Department (ERCD) of the UK Civil Aviation Authority (CAA).
- ANCON noise model profiles (LGW 2015) are used as input to the ANCON model. The UK civil Aircraft Noise Contour Model ANCON is used to calculate contours from aircraft movement, route, noise generation and sound propagation data. One of the outputs from the ANCON model are the above mentioned SEL contours. The profiles were provided to To70 by the Sub-Group, who got them from the ERCD.

The table below shows which sources and methods are used for which analysis.

| Work package | Result | Analysis | Sources |
|--------------|---|---|--|
| WP1 | Key figures: - Number of flights - Time of day - Propulsion - Runway usage - SID usage | - Frequency analysis on radar data - Graphical representation of frequencies - Comparison between years | - Radar data |
| | Flight patterns of consecutive years | - Processing and plotting radar data in a Geographic Information System. - Comparison between years | - Radar data |
| WP2 | Comparison of flight patterns with nominal SID and SEL contours | - Combining the processed and plotted radar data with SID and SEL contours in a Geographic Information System | - Radar data - SEL contours - SID tracks |

¹ <http://casperflights.com/>

| Work package | Result | Analysis | Sources |
|--------------|---|---|----------------------------------|
| | | - Comparison of tracks | |
| WP2 | Vertical profiles | - Processing ² and plotting radar data altitude and speed vs. distance - Comparison between years | - Radar data |
| WP3 | Comparison of vertical profiles with ANCON profiles | - Combining ANCON profiles with the plotted vertical profiles | - Radar data - ANCON profiles |

2.2 Research team

The research was conducted by To70:

| Name | Company | Role |
|-------------------|---------|----------------|
| Jeroen Timmers | To70 | Project leader |
| René van den Berg | To70 | Analyst |
| Mark Verkerk | To70 | Analyst |

2.3 Meetings

The table below lists the meetings held to discuss the (draft) results. During these meetings the scope for additional work was also discussed.

| Date | Meeting | Attendees |
|------------|--|------------------------------------|
| 28-06-2018 | Discussion draft results WP1 (via Skype) | To70, Sub-Group |
| 12-07-2018 | Discussion results WP1 (via Skype) | To70, Sub-Group, Edinburgh Airport |
| 23-11-2018 | Discussion draft results WP2 (via Skype) | To70, Sub-Group |
| 13-12-2018 | Discussion results WP2 (via Skype) | To70, Sub-Group |
| 08-01-2019 | Discussion results WP2 (via Skype) | To70, Sub-Group |
| 22-03-2019 | Discuss draft results WP3 + draft report | To70, Sub-Group, Edinburgh Airport |

² The mean track and standard deviations were determined using a converging search method on the radar tracks

3 Results

The results are presented in graphs and figures, which are grouped by work package in the following appendices:

- Appendix A (WP1)
 - Statistics on the number of aircraft, runway/route usages, aircraft-types and flight-times;
 - Flight-patterns over consecutive years and a comparison between these flight-patterns.
- Appendix B (WP2)
 - A comparison of flight patterns with nominal tracks
 - Altitude/distance and speed/distance plots of aircraft types Airbus A319 and Boeing 737 over consecutive years.
- Appendix C (WP3)
 - Comparison between the measured vertical profiles of altitude and speed and the ANCON profiles.

4 Conclusions

This chapter first presents the conclusions of the initial analysis and further elaborates on these conclusions. These initial conclusions are then followed by the conclusions of the two additional analyses, focusing on the vertical profiles of aircraft and comparing these with the ANCON profiles.

4.1 Conclusions WP1

Conclusion 1: There are no remarkable changes over the years in number of flights, propulsion type, day/evening/night distribution, runway & SID usage

Between 2011 and 2017, the number of flights at Edinburgh Airport increased by 15%. This growth mainly took place in the years following the financial crisis, with around 5% annual growth since 2015. Apart from this growth in traffic, the distribution of traffic do not show large changes. The number of flights during summer show a similar trend to the annual results, indicating that growth took place over the whole year and did not concentrate during the summer months. The spread of traffic over the day has not remarkably changed from its overall 70%/20%/10% (Day/Evening/Night) distribution.

Most aircraft at Edinburgh are jets (around 75%), followed by turbo props (around 25%) and a small amount of propeller aircraft (less than 1%). Between 2011 and 2017 the share of jets gradually decreased from 77% to 72%, which causes a rise in the share of turboprops from 22% to 27%.

The main runway at Edinburgh Airport is runway 24/06. The other runway, RWY 30/12, is rarely used at Edinburgh Airport. Over the years, runway usage has varied slightly (the cause of this is assumed to be variations in wind direction) but the average ratio for 2011-2017 is around 71% RWY24 and 29% RWY06. The analysis of SID usage showed that the GRICE SID (3C and 4D) usage remained constant at 8% over the analysed years. In 2015 a new SID, TUTOR, was trialed for one year after which it was discontinued. During the trial, 5% of departures used the TUTOR SID, which led to a small decrease in GOSAM and TALLA usage for that year. Excluding 2015, the usage of the GOSAM and TALLA SID show variation over the years. In 2011 the GOSAM SID was used more often than the TALLA SID, 52% versus 40%. Over the years GOSAM usage gradually decreased while TALLA increased, changing the ratio to 45% GOSAM and 57% TALLA.

The above findings show that several aspects have changed between 2011 and 2017. However, these were all gradual changes over an extensive period (7 years) and not remarkable/sudden changes in the operation.

Conclusion 2: Later and wider turns in more recent years suggest heavier and/or faster aircraft

Analysis of the track data showed that aircraft turns have changed over the years. In all cases, except for GOSAM 1C (which only turns slightly), aircraft start their turn later and make a wider turn. These later and wider turns could be caused by aircraft being heavier and/or faster, which impacts their turning performance. This assumption has not been investigated further.

Noise Preferential Routes (NPR's)

An attempt was made to compare the radar tracks with the Noise Preferential Routes (NPRs). During this exercise the following was agreed upon by the subgroup and the airport on the status of NPRs at Edinburgh Airport:

Noise Preferential Routes are corridors, extending 1 mile in each direction from the centre of the SID line, which aircraft are expected to fly in when departing from the airport. On occasion, and to ensure aircraft safety, aircraft may be permitted to deviate from the NRP. The most common reason for this is extreme weather conditions in the airport vicinity.

NPRs are not a statutory control but, rather, are used to reduce noise disturbance on local communities. Only airports surrounding London have official NPRs which can only be changed with permission from the DfT. For Edinburgh, NPRs are not a legal requirement. Therefore, NPRs are defined but don't have a formal status like the London airports.

Conclusion 3: Turboprop traffic for SID GRICE in 2016 and 2017 suggest later turns and/or steeper climbs compared to previous years.

For all SIDs the tracks were plotted until an altitude of 4000ft. During the analysis, it was found that turboprop traffic on the SID GRICE varied over the years. In the early years the turboprops made a turn right just after take-off, but the tracks of 2016 and 2017 show a track bundle which stays straighter. This suggests that the turboprops turn later and/or higher on the GRICE SID.

Early turns on GRICE

Inquiries by the airport with ATC showed that during the TUTUR Trial in 2015 it became clear that some flights on GRICE were turning early at 3000ft, rather than the 4000ft as published. This had become the norm for ATC. After the TUTUR trial, the 4000ft turn was enforced to ensure the planes flew as directed, which explains the observed changes in 2016 and 2017.

(Source: E-mail from G. Robertson on the 26th of September 2018)

4.2 Conclusions WP 2

Conclusion 4: There are no remarkable changes over the years in vertical profiles of altitude and speed

Comparing the average vertical profiles of the A319 and B738 for the years 2012, 2014, 2016 and 2018 showed that there are no remarkable differences in either the speed or altitude profiles.

Conclusion 5: There are deviations between the SID procedure and aircraft tracks

Analysis of the track data showed that aircraft tracks deviate from the schematic representation of the SID procedure as published in the AIP. The schematic representation of the SID is a simplification of the

procedure, and is not used for navigating the aircraft. Aircraft / pilots do not follow this exact path. The deviations are visible during and after route turns.

Received SEL noise contours suggest that noise calculations are done with the same schematic representation of the SID, and that noise contours are based on input data that differs from the actual aircraft tracks. These SEL values are the building blocks required to calculate L_{Aeq} .

4.3 Conclusion WP3

Conclusion 6: There are differences between the vertical profiles measured by radar and the ANCON profiles

Comparing the vertical profiles of the A319 and B738 with the provided ANCON profiles showed that there are differences in both speed and altitude. These differences were found in all SIDs, however differences between the SIDs were limited.

For the B738, the altitude profile of the radar tracks show that the aircraft fly higher than assumed in the ANCON profiles. These differences become larger once the distance from the airport becomes larger. The altitude profile of the A319 radar tracks do not deviate considerably from the ANCON altitude profiles.

However, the A319 radar tracks differ from the ANCON profiles with regards to speed. The ANCON profiles assume A319s to reach its maximum speed of 239 kts after 18km, while the speed data from the radar tracks indicate that in reality the A319s keep accelerating. These deviations increase after 8 miles / 13 km from the airport.

The above conclusions confirm suggestions made by the Subgroup that there are deviations between the ANCON model (route and profiles) and the flightpaths and profiles as measured by radar. These deviations increase further away from the airport.

These deviations occur on the input side of the noise-model. It is not possible to conclude how these deviations will affect the output of the noise-model, which are the noise contours.